Glenn Research Center

Cleveland State University

Performance of VDL Modes 2, 3 and 4

Steven Bretmersky*, Vijay K. Konangi* and Robert J. Kerczewski**

*Department of Electrical and Computer Engineering
Cleveland State University
Cleveland, Ohio 44115

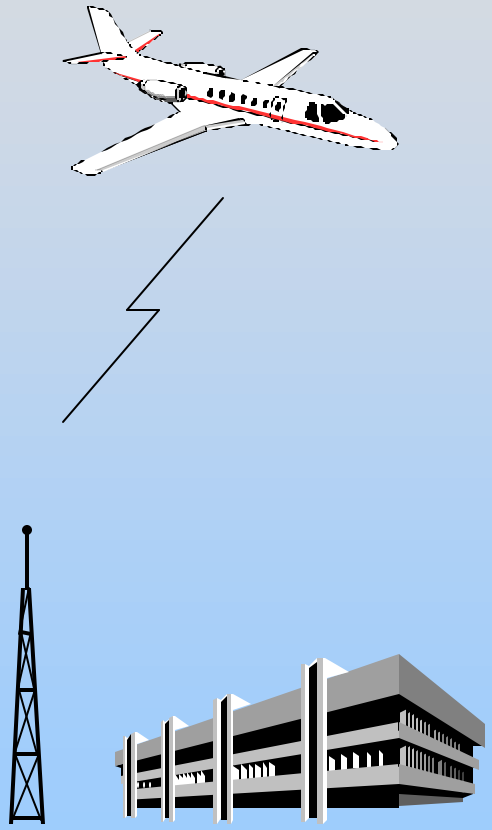
** NASA Glenn Research Center
Cleveland, Ohio 44135

Objective

To evaluate the performance of VDL Modes 2, 3, and 4 around a single ground station

VDL Modes

- VHF Digital Link (VDL) for communication between aircraft and ground stations
- Operate in the Data Link layer of the OSI model
- Use the Aeronautical VHF Band (118 - 137 MHz)
- 4 Modes are specified



The VDL Modes

Mode 1	Mode 2	Mode 3	Mode 4
• Carrier Sense Multiple Access (CSMA)	• Carrier Sense Multiple Access (CSMA)	• Time Division Multiple Access (TDMA)	• Self-Organizing TDMA (STDMA)
• Amplitude Modulated Shift Keying (AM-MSK)	• Differential 8 Phase Shift Keying (D8PSK)	• Differential 8 Phase Shift Keying (D8PSK)	• Gaussian-Filtered Frequency Shift Keying (GFSK)
• 2,400 bits per second	• 31,500 bits per second	• 31,500 bits per second	• 19,200 bits per second
• Connection-oriented	• Connection-oriented	• Acknowledged connection-less	• Connection-oriented
• Lacks support for priority	• Lacks support for priority	• Supports Priority (4 levels)	• Built-in support for ADS-B
• Will not be implemented			

Glenn Research Center

VDL Sublayers

Cleveland State University

A VDL system consists of several sublayers:

VDL Management Entity (VME)

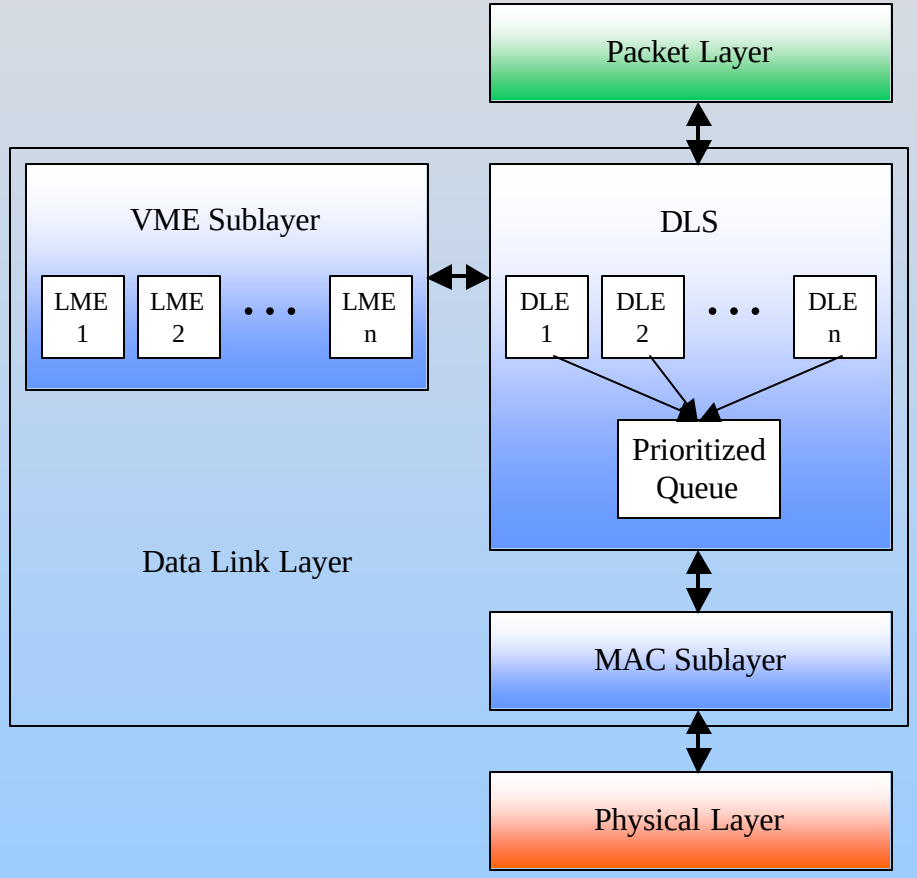
Responsible for connection establishment and handoffs. Creates a Link Management Entity (LME) for each connection

Data Link Sublayer (DLS)

Manages data communication between the aircraft and ground station, providing the addressing and controlling link usage. Maintains a Data Link Entity (DLE) for each connection, and manages a prioritized queue shared by every DLE

Medium Access Control (MAC)

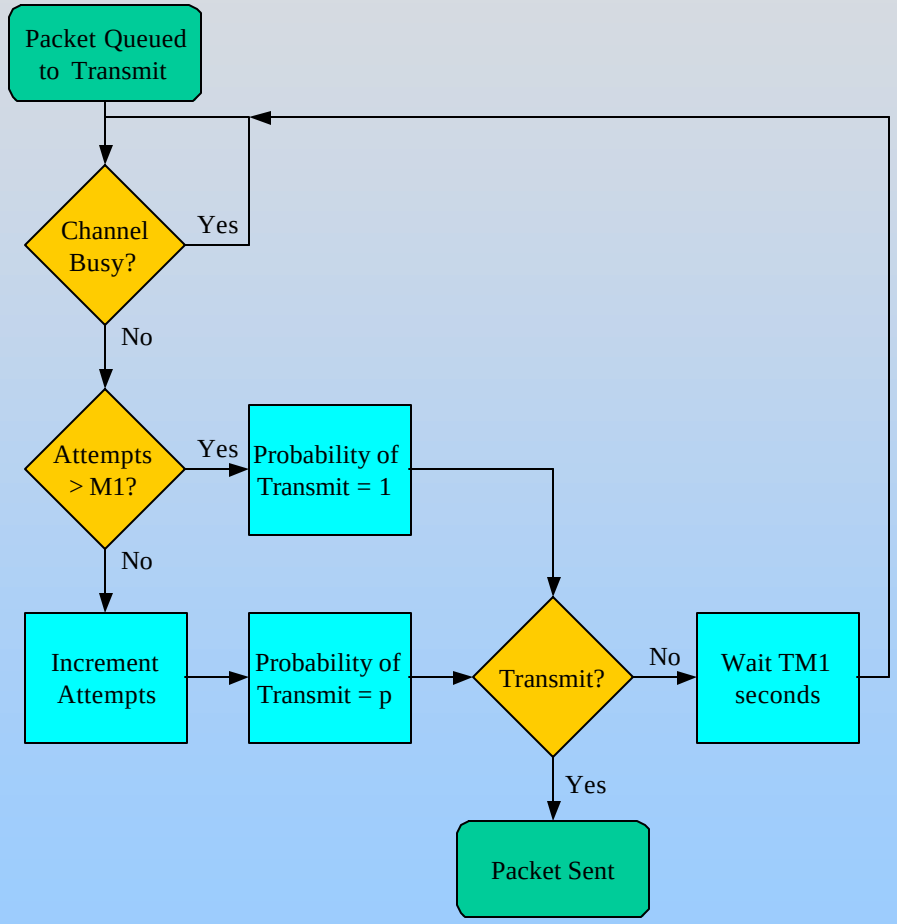
Responsible for determining when to transmit a packet using the link. Different MAC sublayer for each VDL Mode. VDL Mode 4 uses a VDL Mode 4 Specific Services (VSS) sublayer in conjunction with the MAC.



Glenn Research Center

VDL Mode 2

Cleveland State University



MAC Sublayer

- CSMA with backoff
- Maximum access attempts, M1 = 135
- Probability of transmission, p = 13/256
- Backoff time, TM1 = 4.5 ms

DLS Sublayer

- Connection-oriented point-to-point
  - Sliding window
  - Multi-selective reject
  - Dynamic retransmission timer
    - Link utilization
    - Largest retransmission count
- Connection-less broadcast

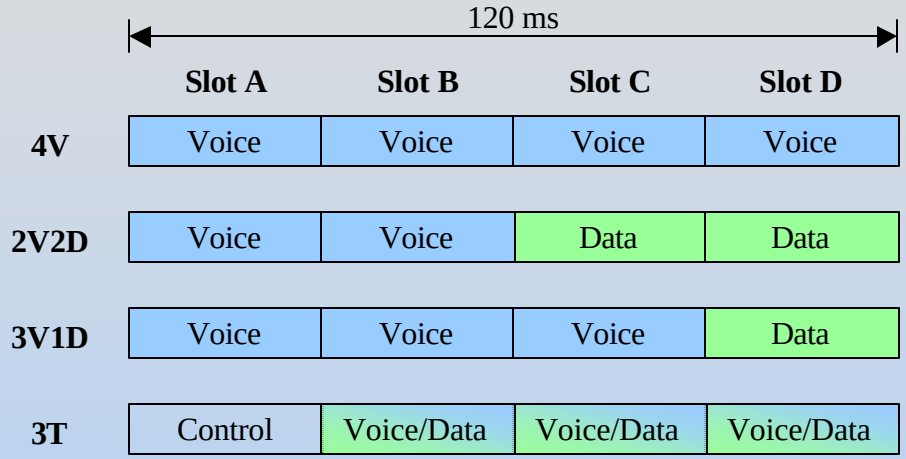
Glenn Research Center

VDL Mode 3

Cleveland State University

MAC Sublayer

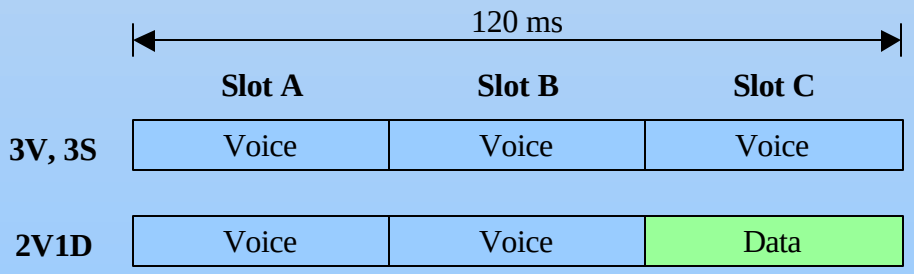
- TDMA
  - Standard range – 4 30ms slots per frame
  - Extended range – 3 40ms slots per frame
  - Two frames per MAC cycle
- Supports voice
- Supports 4 levels of priority



Standard Range Configurations

DLS Sublayer

- Acknowledged connection-less point-to-point
  - Waits for acknowledgement before transmitting next frame
  - Acknowledgement partially handled by MAC
- Connection-less broadcast

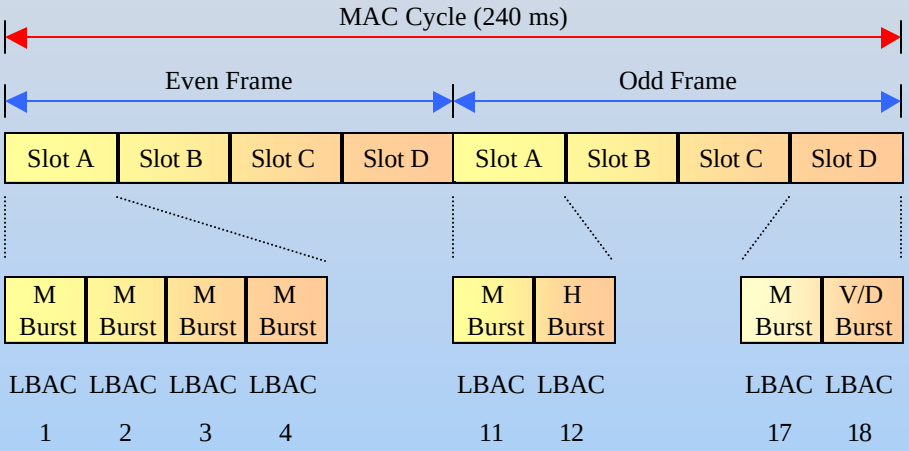


Extended Range Configurations

Glenn Research Center

VDL Mode 3 (3T Data)

Cleveland State University



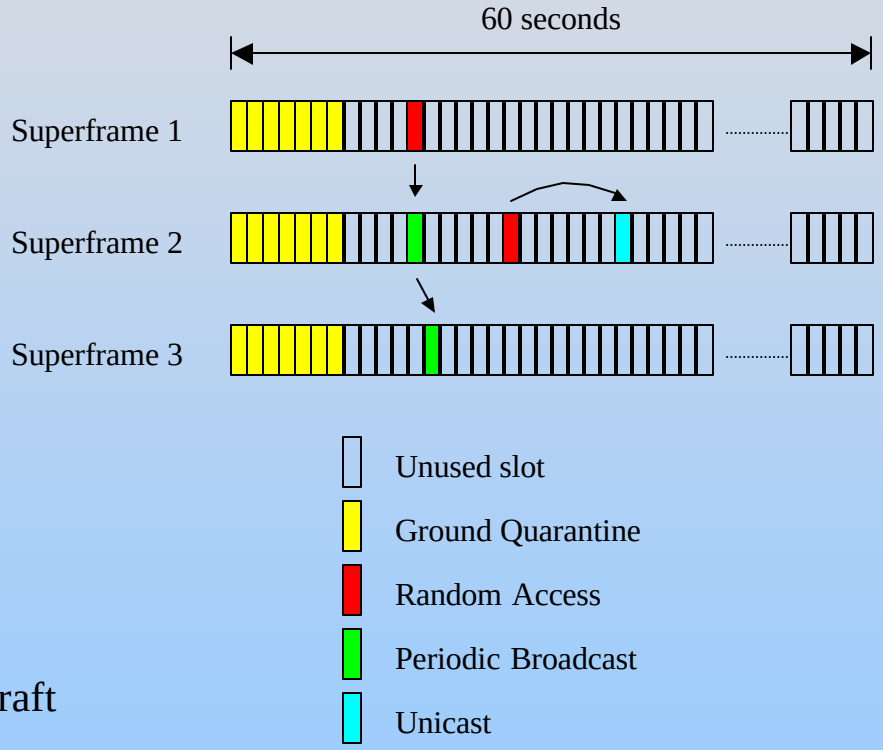
In both frames, Slots B and C are the same as Slot D

- 3 types of bursts
  - Management (M)
  - Handoff Check (H)
  - Voice/Data (V/D)
- 3 groups, one per V/D slot
- 18 Logical Burst Access Channels
  - Slot A
    - 4 M bursts, even frame
    - 1 M and 1 H burst, odd frame
  - Slots B, C, D
    - 1 M and 1 V/D burst
  - All control uplink and timing reference in LBAC 11 M burst
  - All other M bursts for aircraft use by random access, unless reserved for ACK

VDL Mode 4

MAC Sublayer

- STDMA
- 4500 slots per superframe, 1 SF per minute
- Each slot 13.3 ms, or 256 bits long
- Multiple protocols determine access
  - Reserved access
    - Periodic Broadcast
    - Unicast
  - Random access
  - Fixed access
    - Ground Quarantine
- Reserved slots can be reused by distant aircraft
  - Built-in support for ADS-B



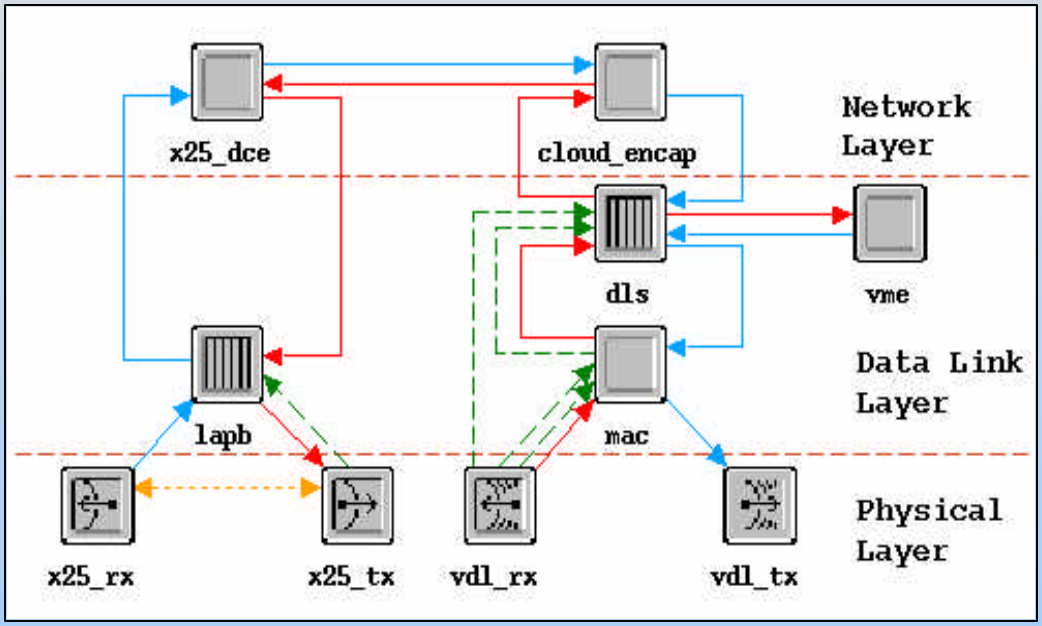
DLS Sublayer

- Same as Mode 2

Glenn Research Center

VDL Transceiver Model

Cleveland State University



The VDL transceiver model used by the aircraft and ground station

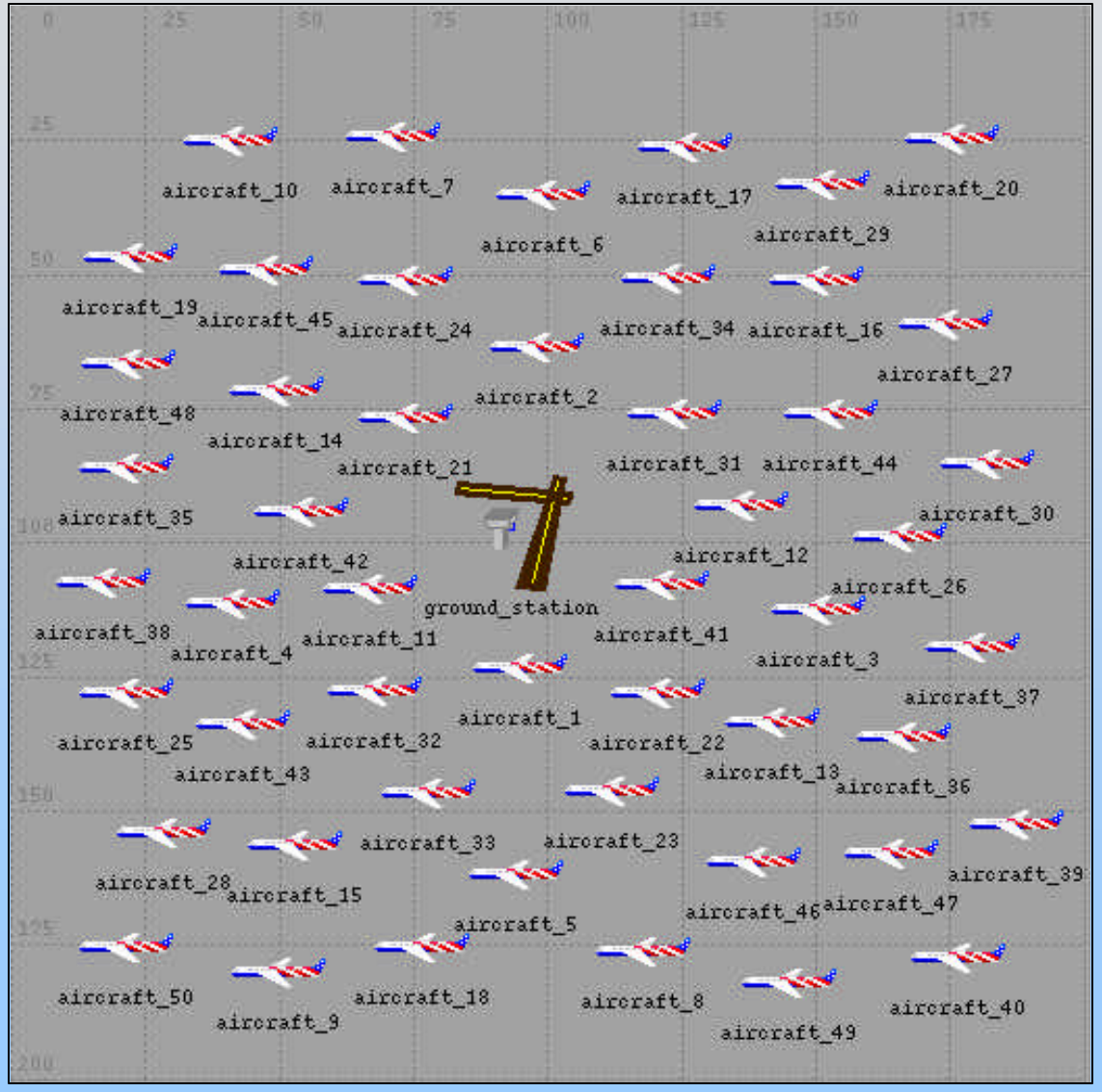
- X.25 Interface
  - Supports connection to an X.25 DTE
  - Uses a maximum packet size of 1024 octets, as per VDL SARPS
- VDL Interface
  - Contains the VME, DLS, and MAC processes

Glenn Research Center

Simulation Scenario

Cleveland State University

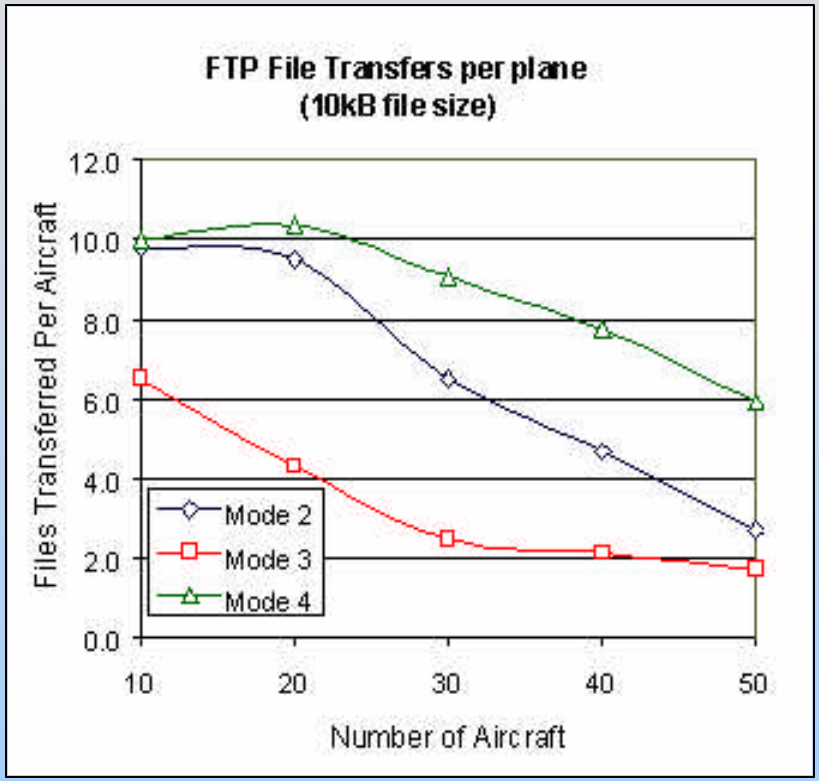
- Ground station modeled as a VDL transceiver connected to a TCP/IP-based server
- Aircraft contain the VDL transceiver connected to a TCP/IP client.
- Simulations with 10, 20, 30, 40, and 50 aircraft surrounding a single ground station.
- Internet applications FTP and HTTP were used to generate traffic.
- Each simulation for a period of 1 hour, in which all the aircraft were in contact with the ground station.



Glenn Research Center

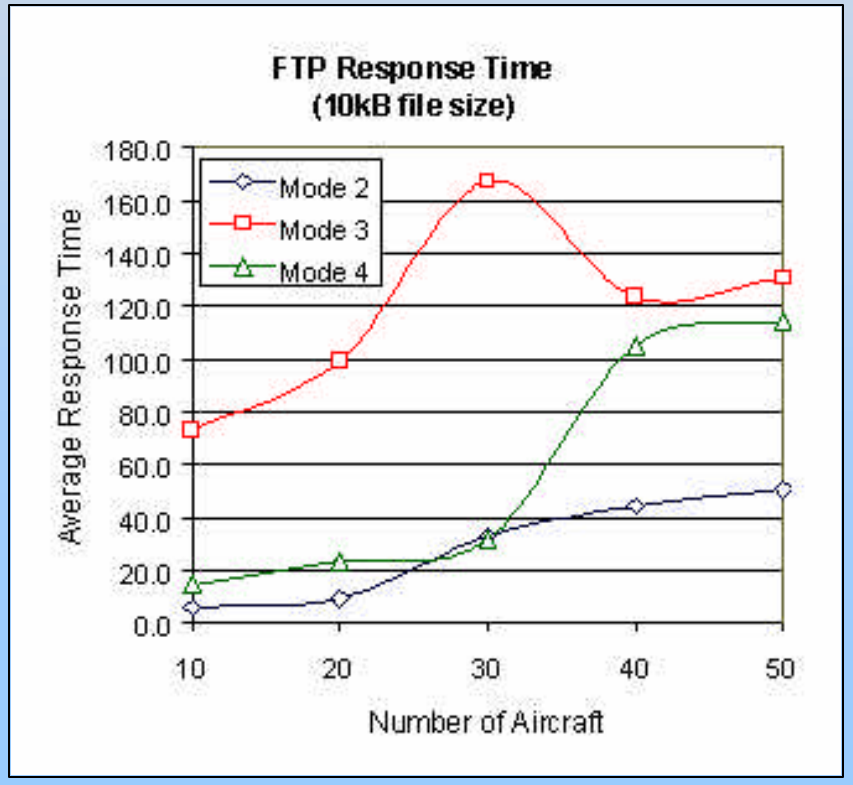
Results (FTP)

Cleveland State University



The FTP simulations with a 10 kB file size show that overall Mode 4 performs the best, with the most number of transfers per aircraft.

The FTP response times show that overall VDL Mode 2 has the lowest delays in this scenario, while VDL Mode 3 has the highest.

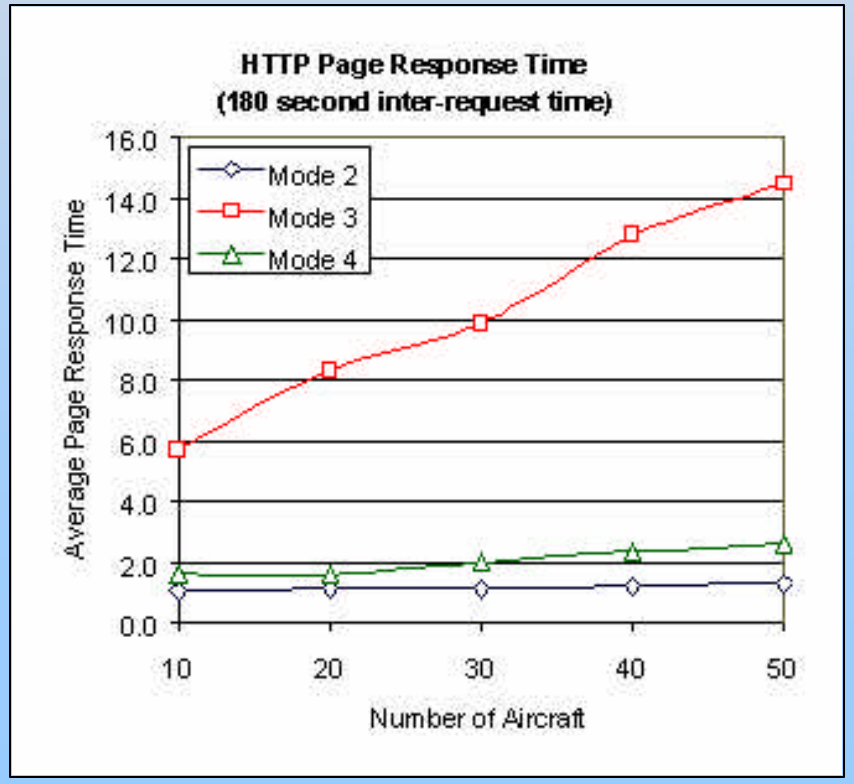


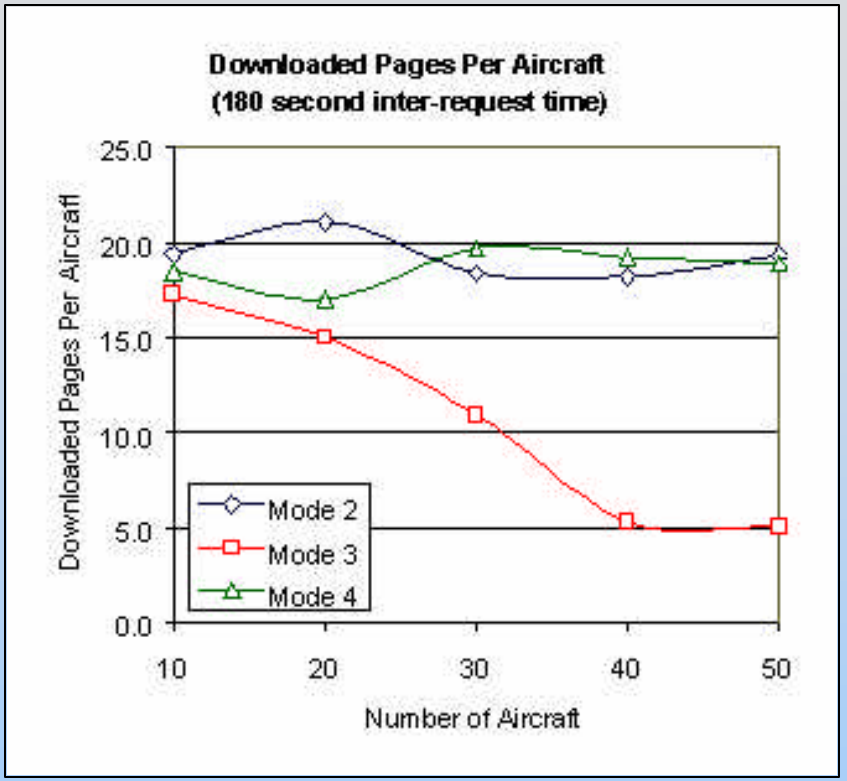
Glenn Research Center

Results (HTTP)

Cleveland State University

The HTTP transfers with 180-second inter-request time showed VDL Modes 2 and 4 transferring a similar number of HTTP pages during the simulation. Mode 3 had fewer transfers per aircraft, and the number declined as the number of aircraft increased.





Response times gives insight into the behavior of the three modes. Mode 3 has the largest response times, which grows as the number of aircraft increases. Modes 2 and 4 are similar and times increase marginally with the number of aircraft.

Conclusions

- VDL Mode 3 has inherently larger delays than Modes 2 and 4
  - A single packet may be transmitted over 15 frames (1.8 s)
- Mode 3 is hindered by large overhead
  - Only 45.7% of the bandwidth is allocated to Voice/Data (3T)
- Mode 4 performs well, even though its data rate is 40% lower than Modes 2 and 3
  - Use of smaller packet sizes should increase performance
- More simulations need to be performed
  - More aircraft
  - Realistic ATN traffic
  - Multiple ground stations

Glenn Research Center

Acknowledgment

Cleveland State University

The authors would like to thank the Advanced Communications for Air Traffic Management (AC/ATM) Project at NASA Glenn Research Center, Cleveland, Ohio for supporting this research